An introduction to remote sensing

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INTRODUCTION TO REMOTE SENSING

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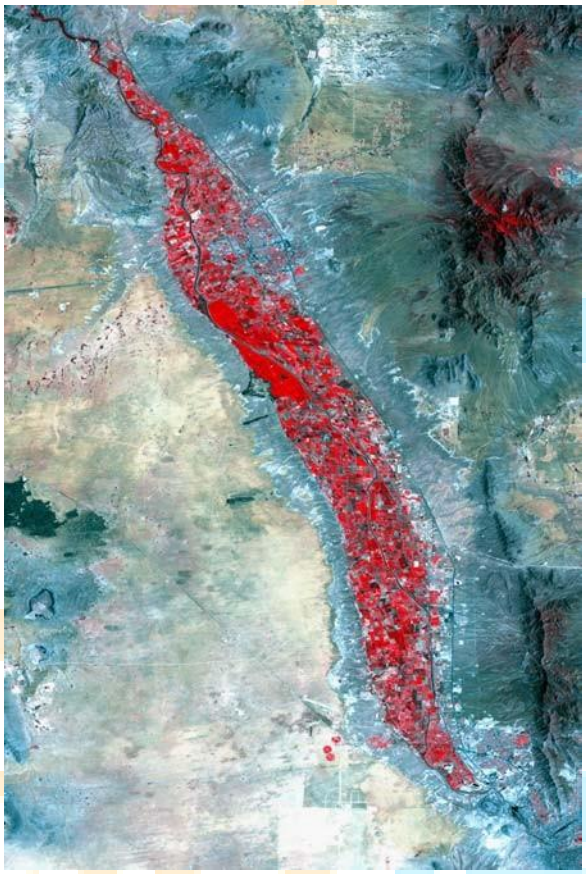

Satellite picture of Las Cruces, NMISROIS087

INDIAN SPACE RESEARCH ORGANISATION

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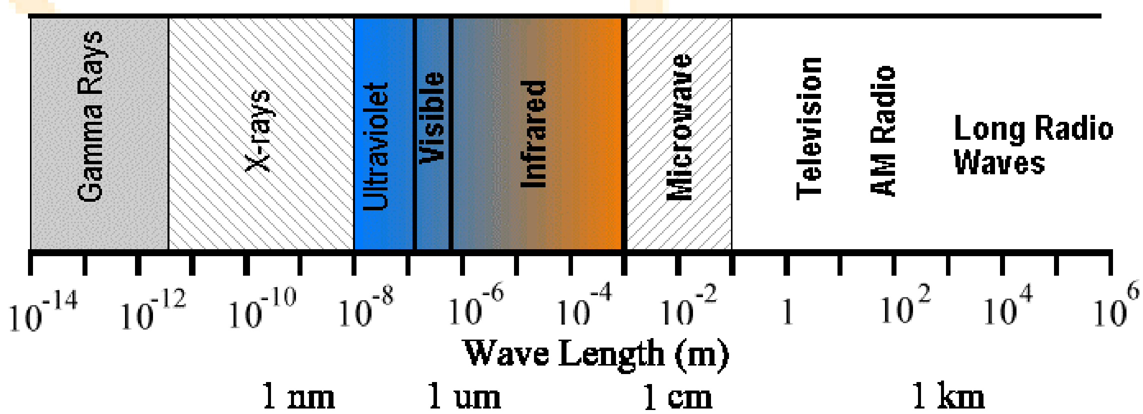
Introduction

Remote sensing can be broadly defined as the collection and interpretation of information about an object, area, or event without being in physical contact with the object. Aircraft and satellites are the common platforms for remote sensing of the earth and its natural resources. Aerial photography in the visible portion of the electromagnetic wavelength was the original form of remote sensing but technological developments has enabled the acquisition of information at other wavelengths including **near infrared**, **thermal infrared** and **microwave**. Collection of information over a large numbers of wavelength bands is referred to as **multispectral** or **hyperspectral** data. The development and deployment of manned and unmanned satellites has enhanced the collection of remotely sensed data and offers an inexpensive way to obtain information over large areas. The capacity of remote sensing to identify and monitor land surfaces and environmental conditions has expanded greatly over the last few years and remotely sensed data will be an essential tool in natural resource management.

Electromagnetic energy

The **electromagnetic (EM) spectrum** is the continuous range of electromagnetic radiation, extending from gamma rays (highest frequency & shortest wavelength) to radio waves (lowest frequency & longest wavelength) and including visible light.

The EM spectrum can be divided into seven different regions —— **gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves** and **radio waves**.



Remote sensing involves the measurement of energy in many parts of the electromagnetic (EM) spectrum. The major regions of interest in satellite sensing are visible light, reflected and emitted infrared, and the microwave regions. The measurement of this radiation takes place in what are known as **spectral bands.** A spectral band is defined as a discrete interval of the EM spectrum. For example the wavelength range of 0.4µm to 0.5µm **(µm = micrometers or 10^{-6}m)** is one spectral band. Satellite sensors have been designed to measure responses within particular spectral bands to enable the discrimination of the major Earth surface materials. Scientists will choose a particular spectral band for data collection depending on what they wish to examine. The design of satellite sensors is based on the absorption characteristics of Earth surface materials across all the measurable parts in the EM spectrum.

Reflection and absorption

When radiation from the Sun reaches the surface of the Earth, some of the energy at specific wavelengths is absorbed and the rest of the energy is reflected by the surface material. The only two exceptions to this situation are if the surface of a body is a perfect reflector or a true black body. The occurrence of these surfaces in the natural world is very rare. In the visible region of the EM spectrum, the feature we describe as the color of the object is the visible light that is not absorbed by that object. In the case of a green leaf, for example, the blue and red wavelengths are absorbed by the leaf, while the green wavelength is reflected and detected by our eyes.

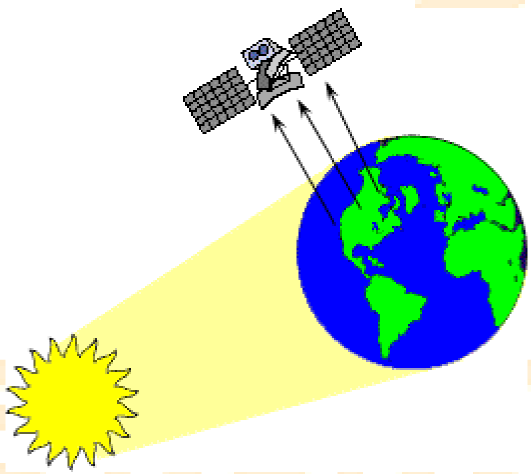
In remote sensing, a detector measures the **electromagnetic (EM) radiation** that is reflected back from the Earth's surface materials. These measurements can help to distinguish the type of land covering. Soil, water and vegetation have clearly different patterns of reflectance and absorption over different wavelengths.

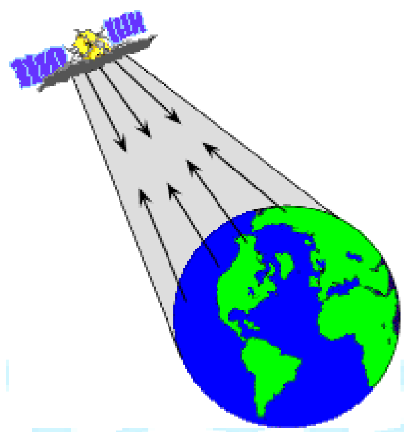
The reflectance of radiation from one type of surface material, such as soil, varies over the range of wavelengths in the EM spectrum. This is known as the **spectral signature** of the material. All Earth surface features, including minerals, vegetation, dry soil, water, and snow, have unique spectral reflectance signatures, as discussed later.

Sensors and platforms

A sensor is a device that measures and records electromagnetic energy. Sensors can be divided into two groups. **Passive sensors** depend on an external source of energy, usually the sun. The most common passive sensor is the photographic camera. **Active sensors** have their own source of energy, an example would be a radar gun. These sensors send out a signal and measure the amount reflected back. Active sensors are more controlled because they do not depend upon varying illumination conditions

Passive sensors **Active sensors**





Orbits and swaths

The path followed by a satellite is referred to as its orbit. Satellites which view the same portion of the earth's surface at all times have **Geostationary** orbits.Weather and communication satellites commonly have these types of orbits. Many satellites are designed to follow a north south orbit which, in conjunction with the earth's rotation (west-east), allows them to cover most of the earth's surface over a period of time. These are **Near-polar** orbits. Many of these satellites orbits are also **Sun-synchronous** such that they cover each area of the world at a constant local time of day. Near polar orbits also means that the satellite travels nortward on one side of the earth and the southward on the second half of its orbit. These are called **Ascending** and

Descending passes. As a satellite revolves around the earth, the sensor sees a certain portion of the earth's surface. The area imaged is referred to as the **Swath**. The surface directly below the satellite is called the **Nadir point.** Steerable sensors on satellites can view an area (off nadir) before and after the orbits passes over a target.

Satellite sensor characteristics

The basic functions of most satellite sensors is to collect information about the reflected radiation along a pathway, also known as the **field of view (FOV)**, as the satellite orbits the Earth. The smallest area of ground that is sampled is called the **instantaneous field of view (IFOV)**. The IFOV is also described as the pixel size of the sensor. This sampling or measurement occurs in one or many spectral bands of the EM spectrum.

The data collected by each satellite sensor can be described in terms of spatial, spectral and temporal resolution.

Spatial resolution

The spatial resolution (also known as ground resolution) is the ground area imaged for the instantaneous field of view (IFOV) of the sensing device. Spatial resolution may also be described as the ground surface area that forms one pixel in the satellite image. The IFOV or ground resolution of the **Landsat Thematic Mapper (TM)** sensor, for example, is 30 m. The ground resolution of weather satellite sensors is often larger than a square kilometer. There are satellites that collect data at less than one meter ground resolution but these are classified military satellites or very expensive commercial systems.

Temporal resolution

Temporal resolution is a measure of the repeat cycle or frequency with which a sensor revisits the same part of the Earth's surface. The frequency will vary from several times per day, for a typical weather satellite, to 8—20 times a year for a moderate ground resolution satellite, such as

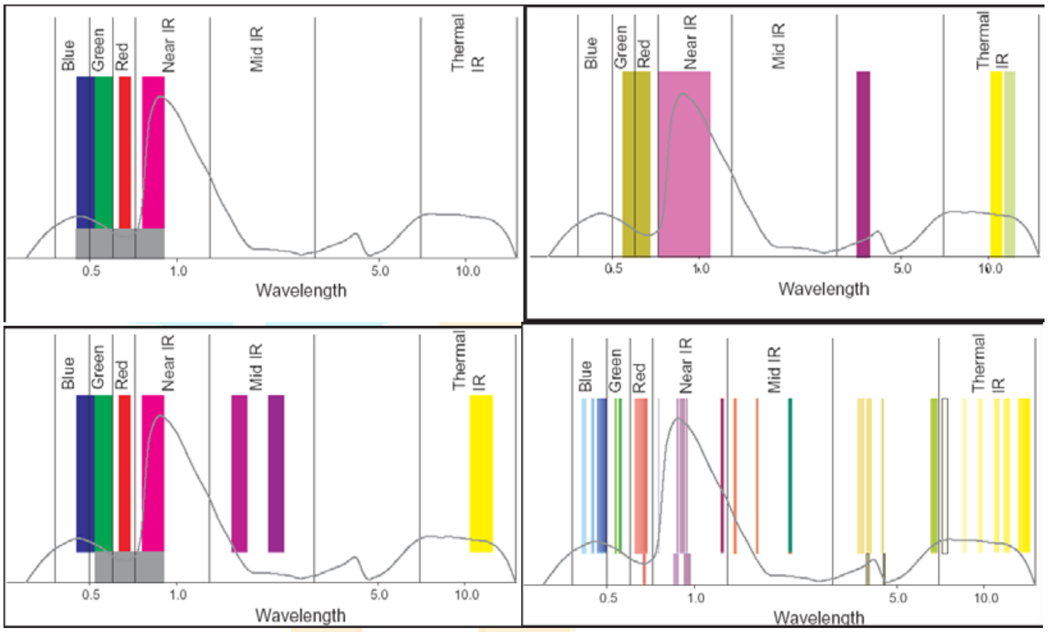
Landsat TM. The frequency characteristics will be determined by the design of the satellite sensor and its orbit pattern.

Spectral resolution

The spectral resolution of a sensor system is the number and width of spectral bands in the sensing device. The simplest form of spectral resolution is a sensor with one band only, which senses visible light. An image from this sensor would be similar in appearance to a black and white photograph from an aircraft. A sensor with three spectral bands in the visible region of the EM spectrum would collect similar information to that of the human vision system. The Landsat TM sensor has seven spectral bands located in the visible and near to mid infrared parts of the spectrum.

A **panchromatic image** consists of only one band. It is usually displayed as a **grey scale image**, i.e. the displayed brightness of a particular pixel is proportional to the pixel digital number which is related to the intensity of solar radiation reflected by the targets in the pixel and detected by the detector. Thus, a panchromatic image may be similarly interpreted as a black-and-white aerial photograph of the area, though at a lower resolution.

Multispectral and hyperspectral images consists of several bands of data. For visual display, each band of the image may be displayed one band at a time as a **grey scale image**, or in combination of three bands at a time as a **color composite image**. Interpretation of a multispectral color composite image will require the knowledge of the **spectral reflectance signature** of the targets in the scene.



Platforms

Aerial photography has been used in agricultural and natural resource management for many years. These photographs can be black and white, color, or color infrared. Depending on the camera, lens, and flying height these images can have a variety of scales. Photographs can be used to determine spatial arrangement of fields, irrigation ditches, roads, and other features (figure 3 on page 8) or they can be used to view individual features within a field (figure 4 on page 8).

Infrared images can detect stress in crops before it is visible with the naked eye. Healthy canopies reflect strongly in the infrared spectral range, whereas plants that are stressed will reflect a dull color (figure 5 on page 9). These images can tell a farmer that there is a problem but does not tell him what is causing the problem. The stress might be from lack of water, insect damage, improper nutrition or soil problems, such as compaction, salinity or inefficient drainage.

The farmer must assess the cause of the stress from other information. If the dull areas disappear on subsequent pictures, the stress could have been lack of water that was eased with irrigation. If the stress continues it could be a sign of insect infestation. The farmer still has to conduct in-field assessment to identify the causes of the problem. The development of cameras that measure reflectance in a wider range of wavelengths may lead to better quantify plant stress. The use of these multi-spectral cameras are increasing and will become an important tool in precision agriculture.

Satellite remote sensing is becoming more readily available for use in precision agriculture. The **Landsat** and the **NOAA** polar-orbiting satellites carry instruments that can be used to determine crop types and conditions, and to measure crop acreage. The **Advanced Very High Resolution Radiometer (AVHRR)** carried onboard NOAA polar orbiting satellites measure reflectance from the earth's surface in the visible, near infrared, and thermal infrared portions of the electromagnetic spectrum. Figure 6 on page 9 shows a typical image obtained from this satellite. This spectral sensitivity makes it suitable for measuring vegetative condition and because the satellite passes overhead twice a day, it can be used to detect rapidly changing conditions. Unfortunately, its use as a precision agriculture tool is limited because the spatial resolution of the sensor is nominally 1.1km. A possible application of this scanner would be to use the thermal infrared sensor to estimate daily maximum and minimum temperatures. These temperature estimates could then be used to determine degree-days that will drive pest development models. Degree-day models are an essential part of IPM programs and the enhanced spatial coverage provided by satellites would allow for assessment of spatial variability in predicted events that is not possible with data from sparsely spaced weather stations currently used for these models. Remotely sensed data can also be used to determine irrigation scheduling and adequacy of irrigation systems for uniformly wetting an entire field.

The sensors aboard the Landsat satellite measures reflected radiation in seven spectral bands from the visible through the thermal infrared. The sensors high spatial resolution (approximately 30m) makes it useful in precision agriculture. Figure 7 on page 10 shows a typical image obtained from this satellite. The spectral response and higher spatial resolution make it suitable for assessing vegetative condition for individual fields but the overpass frequency is only once every 16 days. The less frequent overpass makes it difficult to use these data for assessing rapidly changing events such as insect outbreaks or water stress. New satellites with enhanced capabilities are planned and remotely sensed data will become more widely used in management support systems.

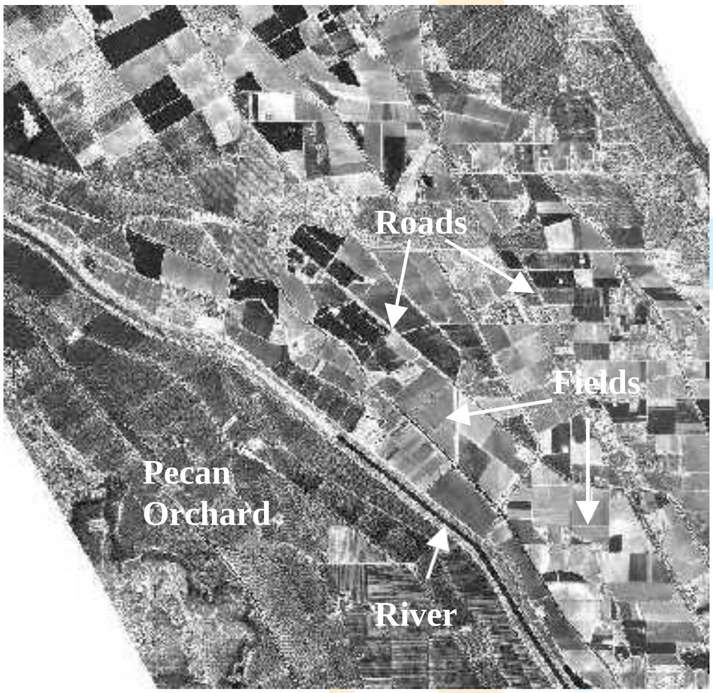


Figure 3. A black and white aerial photograph showing fields, roads, and irrigation ditches.

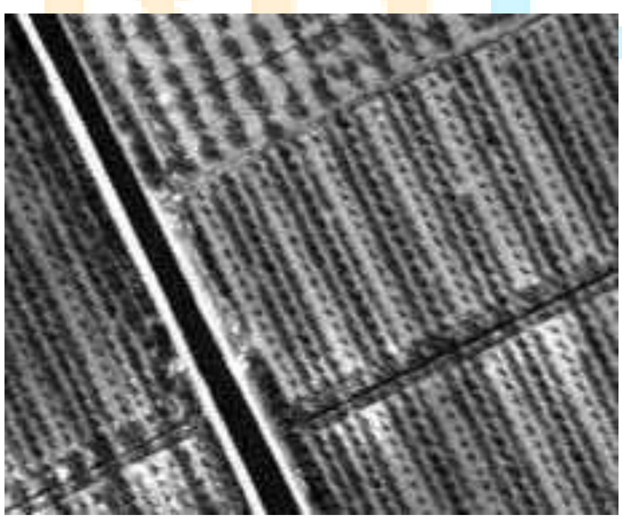


Figure 4. A high resolution aerial photograph showing individual trees within a orchard.

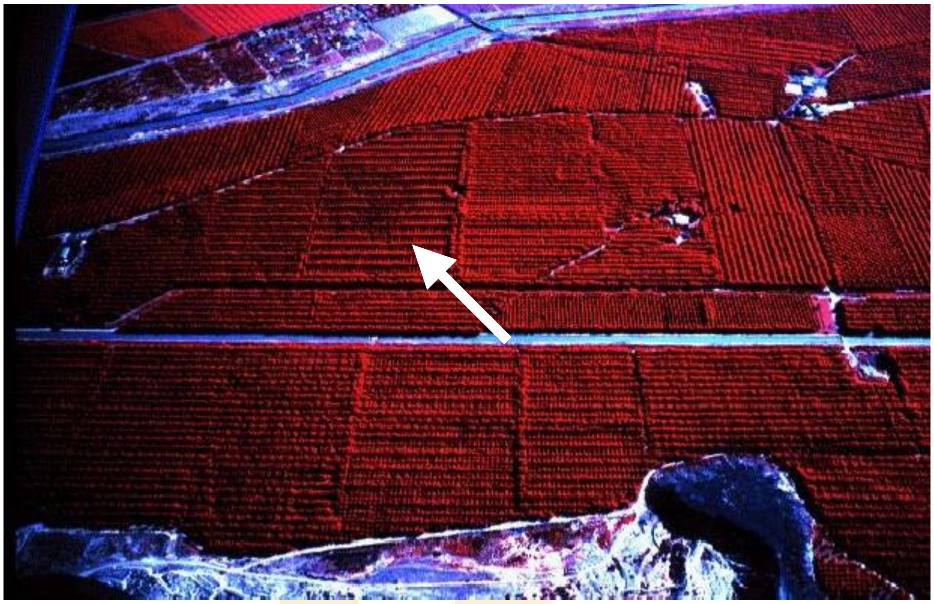


Figure 5. A color infrared photograph of a pecan orchard. Darker areas show stressed plants.

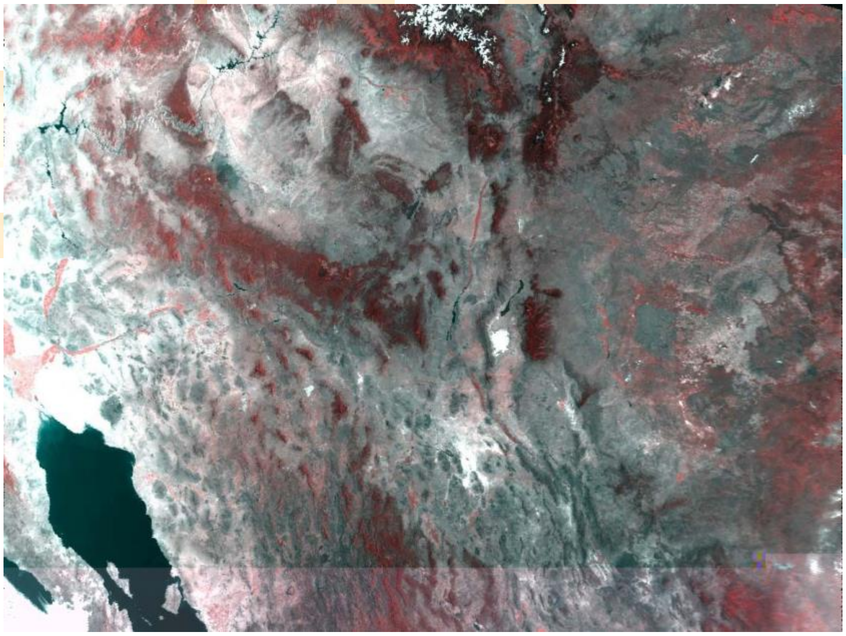


Figure 6. Advanced Very High Resolution Radiometer (AVHRR) image of the southwest Untied

States. Image is centered on the Las Cruces, New Mexico.

Figure 7. A Landsat satellite image of farm land south of Las Cruces, New Mexico.

Common Satellites

GOES
5 spectral bands 1 - 41 km spatial resolution Geostationary

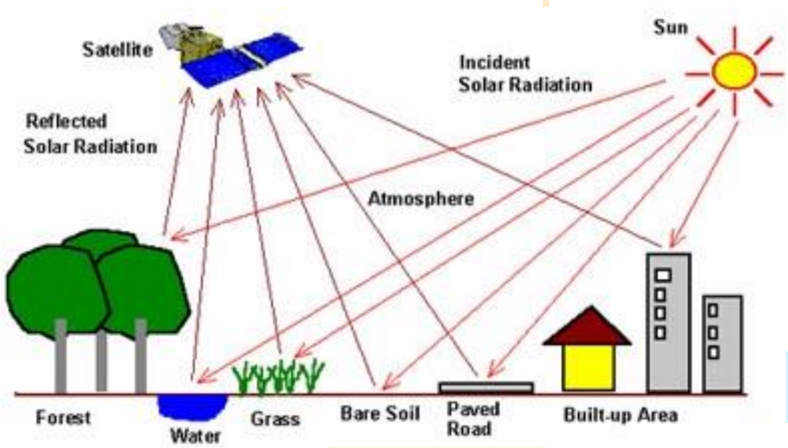
NOAA AVHRR
5 spectral bands 1.1 km spatial resolution 1 day repeat cycle

Landsat TM
7 spectral bands 30m spatial resolution 16 day repeat cycle

MODIS
Multi- spectral bands 250-1000m spatial resolution (band dependent) 1day repeat cycle

IKONOS
4 spectral Bands 4m spatial resolution 5 day repeat cycle

Spectral signatures of natural and human-made materials

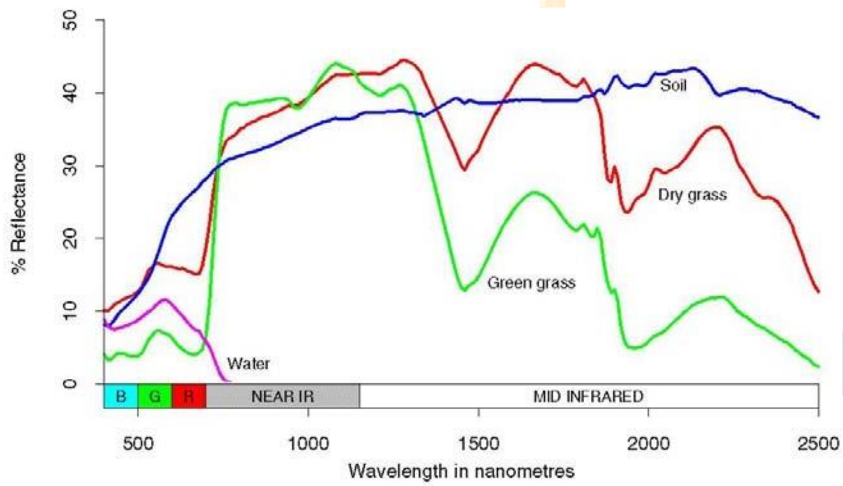


Remote sensing makes use of visible, near infrared and short-wave infrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground. Different materials reflect and absorb differently at different wavelengths. Thus, the targets can be differentiated by their spectral reflectance signatures in the remotely sensed images.

Spectral Reflectance Signature

When solar radiation hits a target surface, it may be **transmitted**, **absorbed** or **reflected**. Different materials reflect and absorb differently at different wavelengths. The reflectance spectrum of a material is a plot of the fraction of radiation reflected as a function of the incident wavelength and serves as a unique signature for the material. In principle, a material can be identified from its spectral reflectance signature if the sensing system has sufficient **spectral resolution** to distinguish its spectrum from those of other materials. This premise provides the basis for multispectral remote sensing.

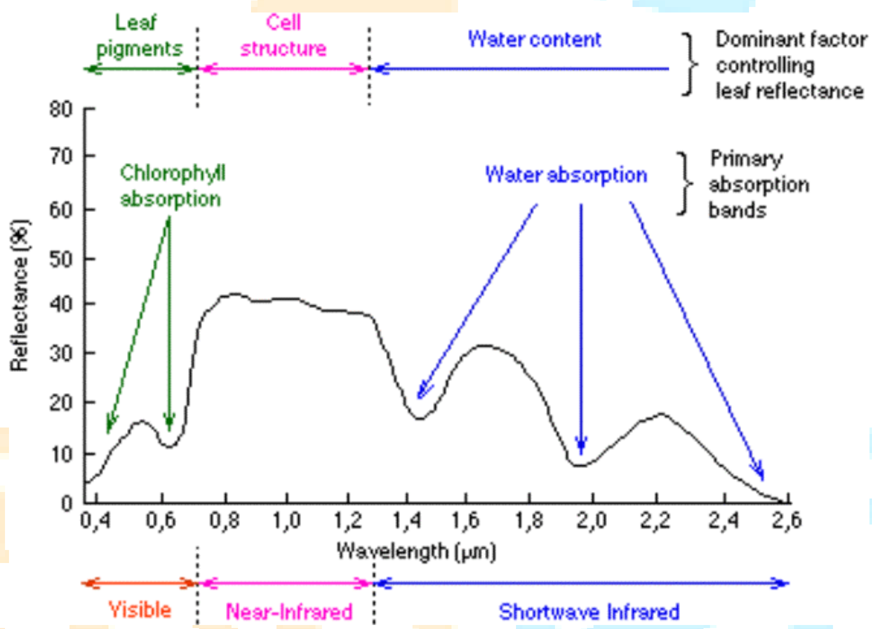
The following graph shows the typical reflectance spectra of water, bare soil and two types of vegetation.



The reflectance of **clear water** is generally low. However, the reflectance is maximum at the blue end of the spectrum and decreases as wavelength increases. Hence, water appears dark-bluish to the visible eye. **Turbid water** has some sediment suspension that increases the reflectance in the red end of the spectrum and would be brownish in appearance. The reflectance of **bare soil** generally depends on its composition. In the example shown, the reflectance increases monotonically with increasing wavelength. Hence, it should appear yellowish-red to the eye.

Vegetation has a unique spectral signature that enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. The reflectance is low in both the blue and red regions of the spectrum, due to absorption by chlorophyll for photosynthesis. It has a peak at the green region. In the **near infrared (NIR)** region, the reflectance is much higher than that in the **visible** band due to the cellular structure in the leaves. Hence, vegetation can be identified by the high NIR but generally low visible reflectance. This property has been used in early reconnaissance missions during war times for "camouflage detection".

The shape of the reflectance spectrum can be used for **identification of vegetation type**. For example, the reflectance spectra of dry grass and green grass in the previous figures can be distinguished although they exhibit the generally characteristics of high NIR but low visible reflectance. Dry grass has higher reflectance in the visible region but lower reflectance in the NIR region. For the same vegetation type, the reflectance spectrum also depends on other factors such as the leaf moisture content and health of the plants. These properties enable **vegetation condition** to be monitored using remotely sensed images.



Geodesy, Geodetic Datums and Map Projections

Geodesy is the branch of science concerned with the determination of the size and shape of the Earth. Geodesy involves the processing of survey measurements on the curved surface of the Earth, as well as the analysis of gravity measurements. Knowing the exact location of a pixel on the Earth's surface (its spatial location) is an essential component of remote sensing. It requires a detailed knowledge of the size and the shape of the Earth.

The Earth is not a simple sphere. Topographic features such as mountain ranges and deep oceans disturb the surface of the Earth. The ideal reference model for the Earth's shape is one that can represent these irregularities and identify the position of features through a co-ordinate system. It should also be easy to use.

Flat Earth vs curved Earth

The "flat Earth" model is not appropriate when mapping larger areas. It does not take into account the curvature of the Earth.

A "curved Earth" model more closely represents the shape of the Earth. A spheroid best represents the shape of the Earth because it is significantly wider at the equator than around the poles (Unlike a simple sphere). A spheroid, (also known as an ellipsoid) represents the equator as an elliptical shape, rather than a round circle. Surveying and navigation calculations can he performed over a large area when a spheroid is used as a curved Earth reference model.

Sea level and the composition of the Earth's interior

The surface of the sea is not uniform. The Earth's gravitational field shapes it. The rocks that make up the Earth's interior vary in density and distribution, causing anomalies in the gravitational field. These, in turn, cause irregularities in the sea surface. A mathematical model of the sea surface can be formulated; however, it is very complex and not useful for finding geographic positions on a spheroid reference model.

Types of geodetic datum

Based on these ideas, models can be established from which spatial position can be calculated. These models are known as geodetic datums and are normally classified into two types geocentric datum and local geodetic datum.

A geocentric datum is one which best approximates the size and shape of the Earth as a whole.

The center of its spheroid coincides with the Earth's center of mass. A geocentric datum does not seek to be a good approximation to any particular part of the Earth.

A local geodetic datum is used to approximate the size and shape of the Earth's sea surface in a smaller area.

Datums and GIS

Having a standard accurate datum set becomes increasingly important as multiple layers of information about the same area are collected and analyzed. The layers are developed into geographic information systems (GIS), which enable the relationships between layers of data to be examined. In order to function effectively, a GIS must possess one essential attribute. It must have the ability to geographically relate data within and across layers. For example, if a dataset about vegetation is being examined against the data sets for topography and soils, the accurate spatial compatibility of the two datasets is critical.

Map projection coordinates

A map projection is a systematic representation of all or part of of the Earth on a two-dimensional surface, such as a flat sheet of paper. During this process some distortion of distances, directions, scale, and area is inevitable. There are several different types of map projections. No projection is free from all distortions, but each minimizes distortions in some of the above properties, at the expense of leaving errors in others. For example, the commonly used Transverse Mercator projection represents direction accurately, but distorts distance and area, especially those farthest from the equator. Greenland, for example, appears to be much larger than it really is. The Transverse Mercator projection is useful for navigation charts.

Universal Transverse Mercator (UTM)

Universal Transverse Mercator (UTM) is a global spatial system based on the Transverse Mercator projection. UTM divides the Earth into 60 equal zones, each being 6 degrees wide. Each zone is bounded by lines of longitude extending from the North Pole to the South Pole. Imagine an orange consisting of 60 segments. Each segment would be equivalent to a UTM zone.

A rectangular grid coordinate system is used in most map projections. These coordinates are referred to as Eastings and Northings, being distances East and North of an origin. They are usually expressed in metres.

Under the UTM system, each East and North coordinate pair could refer to one of sixty points on Earth — one point in each of the sixty zones. Because of this, the zone number needs to be quoted to ensure the correct point on Earth is being identified.

Global Positioning System

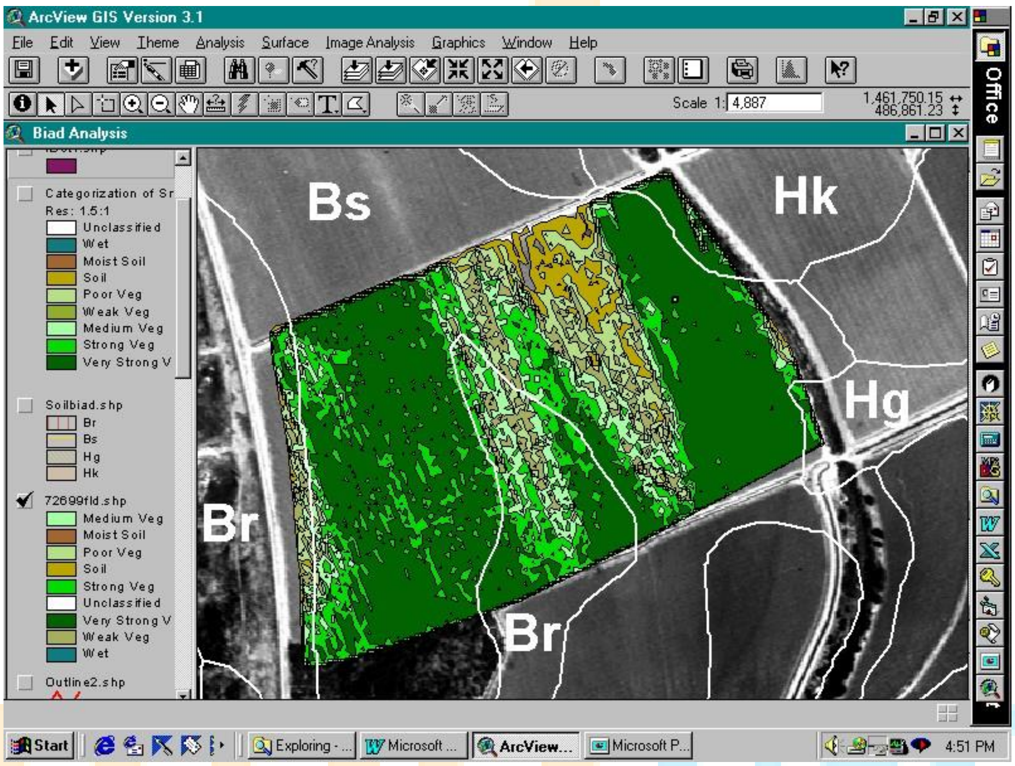
The Global Positioning System (GPS) is a satellite based system that gives real time three dimensional (3D) latitude, longitude, and height information at sub-meter accuracy. The system was developed by the United States military in the late 1970's to give troops accurate position and navigational information. A GPS receiver calculates its position on earth from radio signals broadcast by satellites orbiting the earth. There are currently twenty-four GPS satellites in this system. GPS equipment is capable of measuring a position to within centimeters but the accuracy suffers due to errors in the satellite signals. Errors in the signal can be caused by atmospheric interference, proximity of mountains, trees, or tall buildings. The government can also introduce errors in the signal for security purposes. This intentional degradation of the satellite signals is known as selective availability. The accuracy of the position information can be improved by using differential GPS. In differential GPS, one receiver is mounted in a stationary position, usually at the farm office, while the other is on the tractor or harvesting equipment. The stationary receiver calculates the error and transmits the necessary correction to the mobile receiver. GPS equipment suitable for precision agricultural cost several thousands dollars. Less expensive equipment is becoming available but the accuracy and capability is reduced.

Examples of GPS equipment

Geographic Information System (GIS)

A Geographic Information System (GIS) is a computer-assisted system for handling spatial information. GIS software can be considered as a collection of software programs to acquire, store, analyze, and display information. The input data can be maps, charts, spreadsheets, or pictures. The GIS software can analyze these data using image processing and statistical procedures. Data can be grouped together and displayed as overlays. Overlays could be information such as soil type, topography, crop type, crop yield, pest levels, irrigation, and management information as shown.

The figure below shows a categorized aerial photograph overlaid with soil information using GIS software.

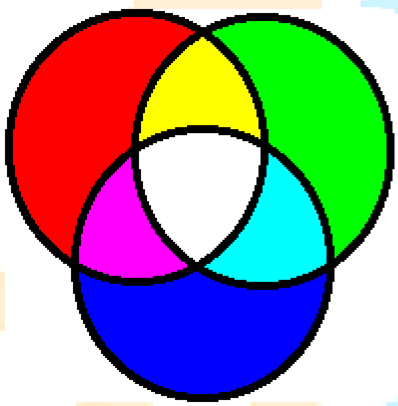


Relationships can be examined and new data sets produced by combining a number of overlays. These data sets can be combined with models and decision support systems to construct a powerful management tool. For example, we could assess how far a field was from roads or non-agricultural crops. This information could be important in pest infestation or in planning chemical application. We could also examine crop yield relationship to soil type or other factors as show in the following figure.. A number of GIS software packages are now commercially available. Spatial data for the GIS is often collected using GPS equipment but another source of spatial information is aerial and satellite imagery.

Pixels, Images and colors

Color Composite Images

In displaying a color composite image, three primary colors (red, green and blue) are used. When these three colors are combined in various proportions, they produce different colors in the visible spectrum. Associating each spectral band (not necessarily a visible band) to a separate primary color results in a color composite image.



Many colors can be formed by combining the three primary colors **(Red, Green, Blue)** in various proportions.

False Color Composite

The display color assignment for any band of a **multispectral image** can be done in an entirely arbitrary manner. In this case, the color of a target in the displayed image does not have any resemblance to its actual color. The resulting product is known as a **false color composite** image. There are many possible schemes of producing false color composite images. However, some scheme may be more suitable for detecting certain objects in the image.

Natural Color Composite

When displaying a natural color composite image, the spectral bands (some of which may not be in the visible region) are combined in such a way that the appearance of the displayed image resembles a visible color photograph, i.e. vegetation in green, water in blue, soil in brown or grey, etc. Many people refer to this composite as a "**true color**" composite. However, this term may be misleading since in many instances the colors are only simulated to look similar to the "true" colors of the targets.

For example, the bands 3 (red band), 2 (green band) and 1 (blue band) of a **AVHRR** image can be assigned respectively to the R, G, and B colors for display. In this way, the color of the resulting color composite image resembles closely what the human eyes would observe.

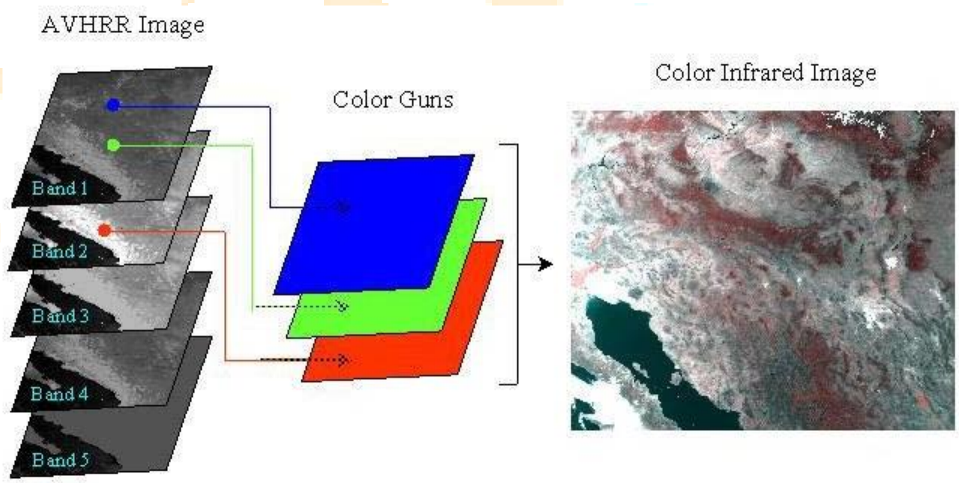
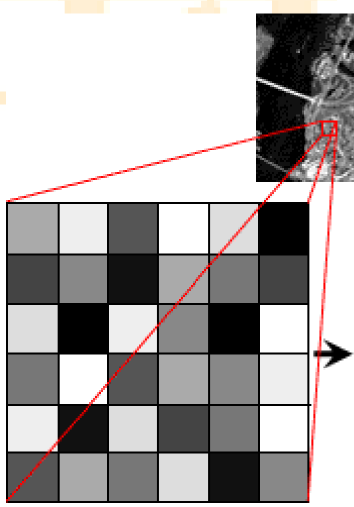


Image processing and analysis

Many image processing and analysis techniques have been developed to aid the interpretation of remote sensing images and to extract as much information as possible from the images. The choice of specific techniques or algorithms to use depends on the goals of each individual project. The key steps in processing remotely sensed data are **Digitizing of Images, Image Calibration, Geo-Registration,** and **Spectral Analysis.** Prior to data analysis, initial processing on the raw data is usually carried out to correct for any distortion due to the characteristics of the imaging system and imaging conditions. Depending on the user's requirement, some standard correction procedures may be carried out by the ground station operators before the data is delivered to the end-user. These procedures include **radiometric correction** to correct for uneven sensor response over the whole image and **geometric correction** to correct for geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing). The image may also be transformed to conform to a specific map projection system. Furthermore, if accurate geographical location of an area on the image needs to be known**, ground control points (GCP's)** are used to register the image to a precise map (**geo-referencing**).

Digitizing of Images



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Image digitization is the conversion of an analogue image, such as a photograph, into a series of grid cells. The value of each cell is related to the brightness, color or reflectance at that point. A scanner is a simple way to digitize images. Many modern sensors now produce raw data in digital format.

Image Enhancement

In order to aid visual interpretation, visual appearance of the objects in the image can be improved by **image enhancement** techniques such as grey level stretching to improve the contrast and spatial filtering for enhancing the edges. An example of an enhancement procedure is shown here.

Image Classification

Different landcover types in an image can be discriminated using some **image classification** algorithms using spectral features, i.e. the brightness and "color" information contained in each pixel. The classification procedures can be "supervised" or "unsupervised".

In **supervised classification**, the spectral features of some areas of known landcover types are extracted from the image. These areas are known as the "**training areas**". Every pixel in the whole image is then classified as belonging to one of the classes depending on how close its spectral features are to the spectral features of the training areas.

In **unsupervised classification**, the computer program automatically groups the pixels in the image into separate clusters, depending on their spectral features. Each cluster will then be assigned a landcover type by the analyst.

Each class of landcover is referred to as a "**theme**" and the product of classification is known as a "**thematic map**".

The information derived from remote sensing images are often combined with other auxiliary data to form the basis for a **Geographic Information System (GIS)**. A GIS is a database of different layers, where each layer contains information about a specific aspect of the same area which is used for analysis by the resource scientists.

Image Interpretation

Vegetation Indices

Different bands of a multispectral image may be combined to accentuate the vegetated areas. One such combination is the ratio of the near-infrared band to the red band. This ratio is known as the Ratio Vegetation Index (RVI)

RVI = NIR/Red

Since vegetation has high NIR reflectance but low red reflectance, vegetated areas will have higher RVI values compared to non-vegetated aeras. Another commonly used vegetation index is the **Normalised Difference Vegetation Index (NDVI)** computed by

NDVI = (NIR - Red)/(NIR + Red)

Table 1 shows equations and references for several indices that can be use in vegetation monitoring.

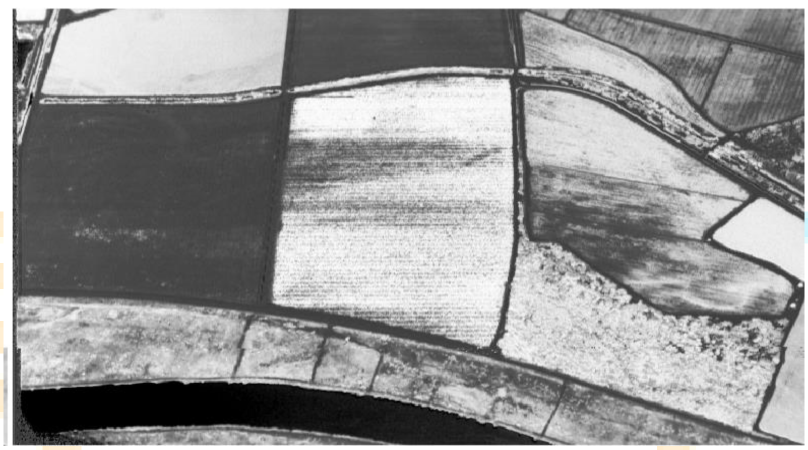
Table1.

PARAMETER	EQUATION	REFERENCE
Normalized Difference Vegetation Index (NDVI)	(NIR-Red)/(NIR+Red)	Rouse et al (1974)
Water Band Index (WBI)	900/970 nm	Pefluelas et al. (1997)
Water Moisture Index (WMI)	1600/820 nm	Hunt and Rock (1989)
Photosynthesis Index	(531-570)/531+570)	Gamon et al. (1990)

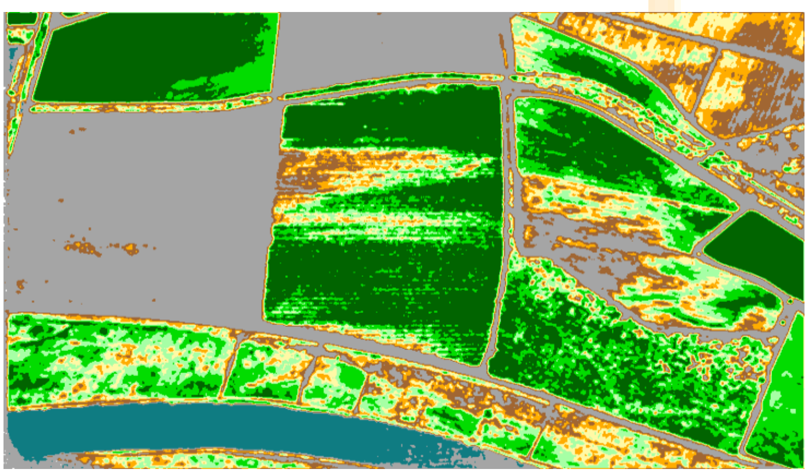
Nitrogen Index (RN)	(550-600)/(800-(900)	Blackmer et al. (1996)
Chlorophyll based Difference Index (CI)	(850-710)/850-680)	Datt (1999)

Example of image processing of aerial infrared photographs to produce a vegetation map for a chile field.

Vegetation maps are produced by generating a normalized difference vegetation index from a infrared image and then doing a vegetation classification.
Color infrared photographs collect information in the green, red and near infrared light reflectance spectrum. Green vegetation reflects very strongly in the near infrared light range and therefore infrared images can detect stress in many crops before it is visible with the naked eye



The Normalized Difference Vegetation Index (NDVI) is used to separate green vegetation from the background soil brightness. It is the difference between the near infrared and red reflectance normalized over the sum of these bands.



NDVI = (IR-Red)/(IR+Red)These NDVI maps can then be classified into vegetation categories and displayed as a vegetation maps with different colors representing different levels of vegetation. In the map on the left browns and yellow represent bare soil and shades of green represent vegetation, darker greens are stronger vegetation.

Current applications of remote sensing

Forestry applications

Satellite imagery is used to identify and map: -

- The species of native and exotic forest trees.
- The effects of major diseases or adverse change in environmental conditions.
- The geographic extent of forests.

This application of satellite imagery has led to the extensive use of imagery by organizations that have an interest in a range of environmental management responsibilities at a state and national level.

Greenhouse gases — sinks and sources

Forests are often referred to as *carbon sinks*. This description is used because during photosynthesis, carbon dioxide, the major greenhouse gas, is taken from the atmosphere and converted into plant matter and oxygen.

Climate change has serious implications for Australia and overseas countries alike. Sustainable land management is essential for effective greenhouse gas management; hence, it is important to acquire data on land cover in Australia. Remotely sensed land cover changes are used in calculations of our national emission levels, and data collected on a national scale will enable governments to develop responses to land clearing.

Vegetation health

Vegetation can become stressed or less healthy because of a change in a range of environmental factors. These factors include lack of water, concentration of toxic elements/herbicides and infestation by insects/viruses. The spectral reflectance of vegetation changes according to the structure and health of a plant. In particular, the influence of chlorophyll in the leaf pigments controls the response of vegetation to radiation in the visible wavelength. As a plant becomes diseased, the cell structure of a plant alters and the spectral signature of a plant or plant community will change.

The maximum reflection of electromagnetic radiation from vegetation occurs in the near infrared wavelengths. Vegetation has characteristically high near-infrared reflectance and low red reflectance. Air-borne scanners using narrow spectral bands between 0.4 urn and 0.9 urn can indicate deteriorating plant health before a change in condition is visible in the plant itself.

Biodiversity

Vegetation type and extent derived from satellite imagery can be combined, with biological and topographic information to provide information about biodiversity. Typically, this analysis is done with a geographic information system.

Change detection

Satellite imagery is not always able to provide exact details about the species or age of vegetation. However, the imagery provides a very good means of measuring significant change in vegetation cover, whether it is through clearing, wildfire damage or environmental stress. The most common form of environmental stress is water deficiency.

Geology

Remote sensing is useful for providing information relevant to the geosciences. For example, remote sensing data are used in:

- Mineral and petroleum exploration,
- Mapping geomorphology, and
- Monitoring volcanoes.

Land degradation

Imagery can be used to map areas of poor or no vegetation cover. A range of factors, including saline or sodic soils, and overgrazing, can cause degraded landscapes.

Oceanography

Remote sensing is applied to oceanography studies. Remote sensing is used, for example, to measure sea surface temperature and to monitor marine habitats.

Meteorology

Remote sensing is an effective method for mapping cloud type and extent, and cloud top temperature.

In many of the applications identified above remotely sensed data are used with a range of other Earth science data to provide information about the natural environment. This analysis of Earth science data from a range of sources is usually done in a geographic information system (GIS).

On-line Tutorials

Introduction to Remote Sensing- Glossary of Terms

Absorption, reflection and transmission - Absorption is the property of an Earth substance or atmospheric gas which absorbs the Sun's radiation. Reflection is when certain materials or gasses contain properties which reflect the Sun's radiation, and transmission is the ability of a substance or gas to pass the Sun's radiation through it. Most materials and gasses possess some of each of these qualities. A healthy green leaf, for example, will absorb the blue and red wavelengths of the Sun's radiation, while reflecting the green wavelengths which are detected by our eyes.

Active remote sensing - Remote sensing methods that provide their own source of electromagnetic radiation to illuminate the target. Radar is an example of active remote sensing, a flash camera is another. (See Passive Remote Sensing).

Albedo - The percentage of incoming radiation that is reflected by a natural surface such as the ground, ice, snow, water, clouds, or particles in the atmosphere.

Analog display - A form of data display in which values are shown in graphic form, such as curves. This differs from digital displays in which values are shown as arrays of numbers.

Anomaly - An area on an image that differs from the surrounding, normal area. For example, a concentration of vegetation within a desert scene constitutes an anomaly.

Azimuth - Geographic orientation of a line given as an angle measured in degrees clockwise from the North.

Azimuth resolution - In radar images, the spatial resolution in the azimuth direction.

Band - A wavelength interval in the electromagnetic spectrum. For example, in Landsat images the bands designate specific wavelength intervals at which images are acquired.

Biome - A community of living organisms in a single major ecological region.

Carbon cycle - The natural cycle of carbon dioxide to carbohydrates by photosynthesis and it's return to the atmosphere by animal metabolism and decomposition.

Chlorosis - The yellowing of plant leaves resulting from an imbalance in the iron metabolism caused by excess concentrations of copper, zinc, manganese, or other elements in the plants. Chlorosis can be detected by infared sensing.

Climatology - The science and study of climates and their phenomena.

Crime mapping - The technology used by the full range of law enforcement agencies to replace the old pins-in-the-map-on-the-wall technique of following crime in an area. Crime mapping utilizes remote sensing and computer technology to create multi-dimensional computer displays of the full range of criminal activity from car theft, vandalism, domestic violence, poverty violence, child abuse, murders, drugs, to prostitution and pickpocketing. The technology of crime mapping allows law enforcement personnel to archive, follow and even predict criminal activity.

Cryosphere - The part of the Earth's surface that is perennially frozen; the zone of the Earth where ice and frozen ground are formed.

Digital display - A form of data display in which values are shown as an array of numbers.

Digital image - An image where the property being measured has been converted from a continuous range of analogue values to a range expressed by a finite number of integers, usually recorded as binary codes from 0 to 255, or as one byte.

Digital image processing - Computer manipulation of the digital-number values of an image.

Digitization - The process of converting an analog display into a digital display.

Diurnal - Daily

Doppler principle - Describes the change in observed frequency that electromagnetic, or other waves undergo as a result of the movement of the source of waves relative to the observer.

Ecosystem - An ecological system composed of interacting organisms and their environments. The result of interaction between biology, geochemical and geophysical systems.

Electromagnetic radiation - Energy propagated in the form of, and advancing interaction between electric and magnetic fields. All electromagnetic radiation travels at the speed of light and its measurement takes place in what are known as spectral bands.

Electromagnetic spectrum (EM) - The continuous sequence or range of electromagnetic energy arranged according to wavelength or frequency. The EM spectrum extends from gamma rays (highest frequency and shortest wave length) to radio waves (lowest frequency and longest wavelength), and includes light rays visible to the human eye. The regions of the EM spectrum include gamma rays, X-rays, ultraviolet, visible light, infared, microwaves, and radio waves.

Electromagnetic wavelength - The distance or time between the alternating cycles of electromagnetic energy.

Ephemeris - A table of predicted satellite orbital locations for specific time intervals. The ephemeris data help to characterize the conditions under which remotely sensed data are collected and are commonly used to correct the sensor data prior to analysis.

False color composite - The display colors for any band of a multispectral image can be assigned in an entirely arbitrary manner, resulting in the color of a target in the displayed image not resembling its “true color”. This is opposed to the natural color composite, or “true color” where the spectral bands are combined or simulated to resemble the true colors of the target as seen by the human eye. (See True Color Composite).

Field of View (FOV) - The pathway along which most satellite sensors collect reflected radiation.

Fluorimetry - The non-destructive analytical technique used to determine concentrations of specific chemical elements. The procedure is based on the artificially induced absorption, atomic excitation, and emission of electromagnetic radiation of characteristic wavelengths.

Geodesy - The branch of science concerned with the determination of the size and shape of the Earth, its surface, and the analysis of gravity measurements.

Geodetic - Knowing or determining the exact location points of a pixel (the spatial location) on the Earth’s surface.

Geodetic accuracy - The accuracy with which geographic position and elevation of features on the Earth’s surface are mapped. This accuracy incorporates information in which the size and shape of the Earth has been taken into account.

Geographic Information System (GIS) - The computer assisted system developed for handling spatial information. GIS software is considered as a collection of software programs which acquire, store, analyze, and display geospatial information.

Geometric correction - To correct for geometric distortion due to Earth’s rotation and other imaging conditions, such as oblique viewing.

Geostationary - Refers to satellites traveling at the angular velocity at which the Earth rotates; as a result, the satellites remain above the same point on Earth at all times.

Geostationary orbit - An orbit at 41,000 km in the direction of the Earth’s rotation, which matches speed so that a satellite remains over a fixed point on the Earth’s surface.

Geothermal - Refers to heat from sources within the Earth.

Global Positioning System (GPS) - The satellite based location system developed by the United States military in the 1970s to give troops accurate position and navigational information. GPS gives real time three dimensional latitude, longitude, and height information at sub-meter accuracy. Currently there are 24 GPS satellites in this system.

GMT - Greenwich mean time. The international 24 hour system used as the prime basis of time throughout the world and to designate the time at which Landsat images are acquired.

GOES - Geostationary Operational Environmental Satellite.

Ground resolution - (spatial resolution) - The ground area imaged for instantaneous field of view of the sensing device. May also be described as the ground surface area that forms one pixel in the satellite image.

Ground swath - The width of the strip of the Earth's surface that is imaged by a scanner system.

Hue - In the Intensity, Hue, and Saturation (IHS) system, hue represents the dominant wavelength of a color.

Hydrology - The scientific study of the waters of the Earth, especially with the relation to the effects of precipitation and evaporation upon the occurrence and character of ground water.

Hyperspectral data - Data gathered from hyperspectral systems, systems capable of taking measurements in many spectral bands, as in the case of the hyperspectral satellite ARIES which takes measurements in over 126 spectral bands.

Hyperspectral image - An image consisting of many more spectral bands of data than multispectral systems.

Instantanenous Field of View (IFOV) - The smallest area of ground that is sampled, also described as the pixel size of the sensor.

Image enhancement - In order to aid visual interpretation, the visual appearance of the objects in the image can be improved by techniques such as grey level stretching to improve the contrast and spatial filtering for enhancing the edges.

LIDAR - Light intensity detection and ranging, which uses lasers to stimulate fluorescence in various compounds and to measure distances to reflecting surfaces.

Luminance - The quantitative measure of the intensity of light from a source.

Mode - The value that occurs most frequently within the data sample being taken. In a histogram, it is the data value at which the peak of the distribution curve occurs.

Mosaic - A composite image or photograph made by piecing together individual images or photographs covering adjacent areas.

Multispectral data - Data collected from several spectral bands.

Multispectral image - An image consisting of several bands of data which requires the knowledge of the spectral reflectance signature to interpret.

Multispectral scanner - A scanner system that simultaneously acquires images of the same scene at different wavelengths.

Nadir - The point on the Earth's surface directly below the center of the remote sensing platform.

Orbit - The path of a satellite around a body such as the Earth, under the influence of gravity.

Panchromatic image - An image consisting of only one band, usually displayed as a grey scale image, or as a low resolution black and white aerial photograph.

Parse - To break down a sequence of numbers or letters into meaningful parts based on their location in the character sequence. For example, the first three numbers in a phone number are the area code numbers that identify the location of the phone number.

Passive remote sensing - Remote sensing of energy naturally reflected or radiated from the target. (See Active Remote Sensing).

Phenololgy or **Phenological** - Refers to the rate and timing of natural events, such as the growth cycle of vegetation over a growing period. Land cover and vegetation types may often be distinguished from each other by their characteristic spectral/temporal signature, as illustrated by a graph plotting values against time through a growing season for several agricultural categories. The shape and position of each curve defines that category's phenological characteristic.

Pixel - An abbreviation of picture element. The minimum size area on the ground detectable by a particular remote sensing device. The size varies depending on the type of sensor.

Planimetric - Two dimensional. The measurements of plane surfaces. A map representing only horizontal features. Parts of a map that represent everything except relief.

Platforms - The vehicles on which remote sensors are mounted, usually satellites and aircraft. Unmanned Air Vehicles (UAV) are used more and more frequently because they are cheaper than a full sized aircraft and a pilot. In addition, remote sensors can be mounted on structures such as bridges (to sense water flow or levels, or traffic patterns over bridges) and buildings (to monitor air quality and pollution in urban areas). Police radar guns are an example of a portable remote sensing device as well as a simple camera.

POES - Polar orbiting environmental satellite.

Primary colors - A set of three colors that in various combinations will produce the full range of colors in the visible spectrum. There are two sets of primary colors, additive and subtractive.

Quantum - The elementary quantity of electromagnetic (EM) energy that is transmitted by a particular wavelength. According to the quantum theory, EM radiation is emitted, transmitted, and absorbed as numbers of quanta, the energy of each quantum being a simple function of the frequency of the radiation.

Radar - The acronym for Radio Detection and Ranging. Radar is an active form of remote sensing that operates in the microwave and radio wavelength regions.

Radiation - The propagation of energy in the form of electromagnetic waves.

Radiometric correction - To correct for uneven sensor response over the entire image.

Reflection, absorption and transmission - Absorption is the property of an Earth substance or atmospheric gas which absorbs the Sun's radiation. Reflection is when certain materials or gasses contain properties which reflect the Sun's radiation, and transmission is the ability of a substance or gas to pass the Sun's radiation through it. Most materials and gasses possess some of each of these qualities. A healthy green leaf, for example, will absorb the blue and red wavelengths of the Sun's radiation, while reflecting the green wavelengths which are detected by the human eye.

Remote link - The direct connection to a computer-based system located at another data center. Links are established via wide area networks and are initiated by the GLIS software. Once connection is established, the control of the user's session is passed to that system.

Remote sensing - The art and science of detecting, measuring and analyzing a substance or object from a distance.

Scanner - An imaging system in which the Instantaneous Field of View (IFOV) of one or more detectors is swept across the terrain.

Soil classifications - The systematic arrangement of soils into groups or categories based on their characteristics. Broad groupings are made on the bases of general characteristics and subdivisions on the premise of more detailed differences in specific properties.

Spatial resolution (ground resolution) - The ground area imaged for instantaneous field of view of the sensing device. May also be described as the ground surface area that forms one pixel in the satellite image. Spatial resolution can be from 1 meter to several km, depending on the precision and scope of the sensing device.

Spectral bands - The discrete intervals of the electromagnetic (EM) spectrum used to measure this radiation.

Spectral reflectance - Reflectance of electromagnetic energy at specified wavelength intervals.

Spectral resolution - The number and width of the spectral bands in a sensing device. The simplest form is a sensor with one band only, which senses visible light. An image from this sensor would be similar in appearance to a black and white photograph from an aircraft.

Spectral signature of the material - The reflectance of radiation from a certain type of the Earth's surface material or other materials in the atmosphere. Minerals, vegetation, soil, water and snow have unique spectral reflectance signatures, as do clouds, fog and smoke.

Swath - A swath of data is all data received from a spacecraft on a single pass from acquisition of signal (AOS) to loss of signal (LOS).

Synthetic Aperture Radar (SAR) - The most common active remote sensing system which emits radar pulses from under an aircraft or satellite onto a given area. The reflected or back-scattered radar signals form an image.

Target - The specific object of interest in a remote sensing investigation.

Temporal resolution - The measure of the repeat cycle or frequency with which a sensor revisits the same part to the Earth's surface. This will vary from several times per day, for a typical weather satellite, to 20 times per year for a moderate ground resolution satellite such as Landsat TM (Thematic Mapper).

Thematic mapping - Each type of land cover is classified into a "theme" and produced on a thematic map.

Transmission, absorption, and reflection - Absorption is the property of an Earth substance or atmospheric gas which absorbs the Sun's radiation. Reflection is when certain materials or gasses contain properties which reflect the Sun's radiation, and transmission is the ability of a substance or gas to pass the Sun's radiation through it. Most materials and gasses possess some of each of these qualities. A healthy green leaf, for example, will absorb the blue and red wavelengths of the Sun's radiation, while reflecting the green wavelengths which are detected by our eyes.

Transpiration - The expulsion of water vapor and oxygen by vegetation.

True color composite - When displaying a natural color composite image, the spectral bands (some of which may not be visible) are combined in such a way that the appearance of the displayed image resembles a visible color photograph, i.e. vegetation in green, water in blue, soil in brown or grey, etc. This may be misleading as, in many instances the colors are only simulated to look similar to the “true” colors of the targets. (See False Color Composite).

Universal Transverse Mercator (UTM) - The global spatial system based on the Transverse Mercator projection. This system divides the Earth into 60 equal zones, each 6 degrees wide, bounded by lines of longitude extending from the North Pole to the South Pole, each segment the equivalent to a UTM zone.
UV - The ultraviolet region of the electromagnetic spectrum ranging in wavelengths from 0.01 to 0.4m.

Virtual fencing - The system by which free ranging animals are controlled, by remote sensing signals and receptors (commonly in the form of ear tags), in their range, or directed to more appropriate terrain for their health, safety and effective use of natural resources.

Zenith - The point on the celestial sphere vertically above a given position or observer.

List of best research & project papers

1. D.satpati and p.v.venkitakrisnan Doubt study of meteorites and their impacts on earth in pslv f 5,8(2) (2018), 240-249. (Atlantis Press and Taylor and Francis) (SCIE)(I.F- 1.151)

2. D.satpati,p.v.venkitakrishnan and a.biswas Doubt a study of glass and silicon carbidefiber reinforced ai{6061} hybrid composite for space application in slv f 21 37 (4) (2018), 5169-5165. (IOS-press) (SCIE) (I.F-1.637)
*** NATIONAL AWARDED & GOLD MEDAL

3. D.satpati and p.v.venkitakrishnan, s. Chatterjee doubt vhf radar measurement of momentum fluxes of gravity waves and tide over lower atmosphere over a tropical station in pslv fs 121 8(4) (2019), 101-121.(IGI Global) .(Scopus)
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4. D.satpati and arghya biswas, Ch. 14. Doubt buckling and non-linear post buckling analysis of stiffened composite shells based on wavelet galerkin projection in gslv f 10, k.sivan and p.k. venkitakrisnan.
1-215 (2019), (IGI Global). doi:10. 978-91-7595-099-0

5. D.satpati and p.v.venkitakrisnan Doubt retrieval and budgeting of soil moisture and data monitoring from irs-p4{oceansat-1} mission data climate of isro., 5(1) (2019).

*** AWARDED GOLD MEDAL

6. D.satpati and sankha chatterjee Doubt study of short period gravity waves and associated momentum fluxes in the tropical middle atmosphere using mst radar and lider. 8 (4)(2020), 593-605. (Kyung MoonSa).

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7. 5. D.satpati, p.v.venkitakrisnan AND sankhadeep agarwal Doubt remote sensing and budgeting of engine fuel device and data monitoring from irs-p5is{pslv c51-1} mission data climate of isro., 5(1) (2020).

*** AWARDED GOLD MEDAL

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